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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04N 9/04

A1

(11) International Publication Number: WO 99/39509

(43) International Publication Date: 5 August 1999 (05.08.99)

(21) International Application Number: PCT/IB99/00073

(22) International Filing Date: 18 January 1999 (18.01.99)

(30) Priority Data:
98200261.0 29 January 1998 (29.01.98) EP

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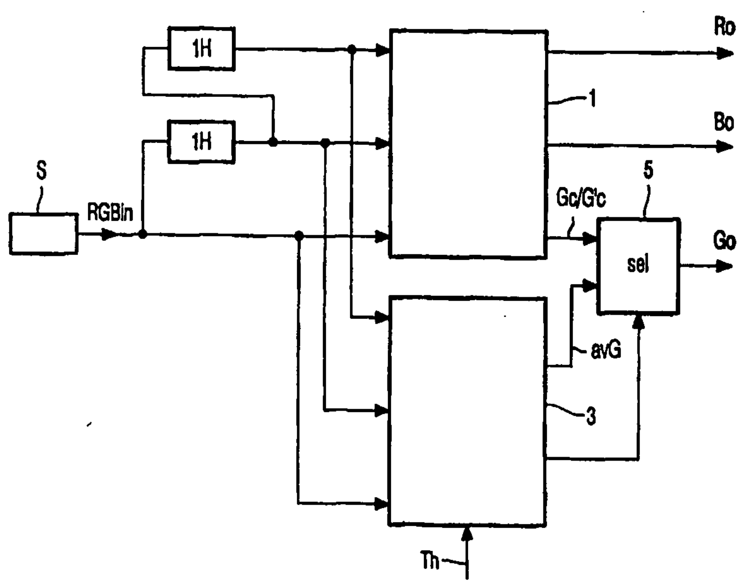
(81) Designated States: JP, KR, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: COLOR SIGNAL INTERPOLATION



(57) Abstract

In a method of interpolating an output color signal (Go) of a given color in dependence on an input signal (RGBin) having first values of the given color which are influenced by a first other color and second values of the given color which are influenced by a second other color, an intermediate color signal (Gc') is interpolated (1) at positions where no signal of the given color is present, an average value (avG) of the given color is generated (3) in dependence upon both the first and second values, and the output color signal (Go) is furnished (5) in dependence upon both the intermediate color signal (Gc') and the average value (avG).

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Color signal interpolation.

The invention relates to interpolation of color signals, and more specifically to restoration of Green uniformity of RGB Bayer sensors.

RGB Bayer sensors have an alternating color pattern of rows having
RGRG etc. colored pixels, and
GBGB etc. colored pixels.
In the vertical direction of a 'Red' column, a Green pixel has only Red pixels as vertically neighboring pixels, while in a 'Blue' column, a Green pixel has only Blue pixels as vertically neighboring pixels. Depending on the quality of the vertical color separation of the sensor, the Green pixels can be modulated by the amount of electron charge in the Red and Blue pixels. If so, then for certain colored scenes this may result in a visible column wise Green non-uniformity. A nice example is a highlighted Cyan color, which theoretically has no Red but only Blue and Green. This will result in a different Green for the Red and Blue columns, which can be visible on a display or on a printout especially because of its regularity. A stylistic example of the column-wise modulation of Green by the electron charges of the Red and Blue pixels is shown in Fig. 1.

It is, *inter alia*, an object of the invention to reduce this Green non-uniformity without losing resolution. To this end, a first aspect of the invention provides a method as defined in claim 1 and a device as claimed in claim 3. A second aspect of the invention provides a camera as defined in claim 4. An advantageous embodiment is defined in the dependent claim 2.

In a method of interpolating an output color signal of a given color in dependence on an input signal having first values of the given color which are influenced by a first other color and second values of the given color which are influenced by a second other color, in accordance with a primary aspect of the present invention an intermediate color signal is interpolated at positions where no signal of the given color is present, an

average value of the given color is generated in dependence upon both the first and second values, and the output color signal is furnished in dependence upon both the intermediate color signal and the average value.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 shows an RGB Bayer sensor in which the Green signal in the columns with Red pixels differs from the Green signal in the columns with Blue pixels;

Fig. 2 indicates a present Green center pixel Gc and four present Green neighboring pixels G1-G4, as well as a reconstructed Green center pixel Gc' and four present Green neighboring pixels G1-G4;

Fig. 3 indicates a present Green center pixel Gc and two present Green neighboring pixels G1-G2, as well as a reconstructed Green center pixel Gc' and three present Green neighboring pixels G1-G3; and

Fig. 4 shows a block diagram of a camera in accordance with the present invention.

In case of a signal processing with two row delays, Fig. 2 shows the declaration of the surrounding Green pixels if Green is present (left) or absent (right). In the latter case, the missing center Green pixel Gc' is reconstructed by means of an RGB reconstruction filter 1 in Fig. 4. Preferably, the RGB reconstruction filter is of the type described in EP patent application no. 97401700.6 filed on 15.07.97 (Attorneys' docket PHN 16,466) and its corresponding applications, incorporated herein by reference.

In practice it appears that the Green non-uniformity is limited to a certain maximum, for instance 5%, of the Green signal amplitude. This Green non-uniformity level Th is preferably adjustable by means of the core of the camera processing. The goal of the Green uniformity restoration is that above that level Th no resolution loss will occur, but that below that level the center Green will be replaced by an averaged Green value of the surrounding green pixels.

The algorithm for Green uniformity restoration which yields the output Green value Go:

```
avG = (G1+G2+G3+G4)/4
if the center Green pixel Gc' has to be interpolated then
begin
        if abs((G1+G2-G3-G4)/2) < Th then
                Go = avG
        else    Go = Gc' (the reconstructed Green)
end
else (the center Green pixel Gc is present)
begin
        if abs(avG-Gc) < Th
        then    Go = (Gc+avG)/2
        else    Go = Gc
end
```

In case of a signal processing with only one row delay, only the pixels illustrated in Fig. 3 are available. In that case the algorithm for Green uniformity restoration is:

```
avG = (G1+G2)/2
if the center Green pixel Gc' has to be interpolated then
begin
        if abs(avG-G3) < Th
        then    Go = (avG+G3)/2
end
else (the center Green pixel Gc is present)
begin
        if abs(avG-Gc) < Th
        then    Go = (Gc+avG)/2
        else    Go = Gc
end
```

A block diagram of how to combine the RGB reconstruction and the Green uniformity restoration is shown in Fig. 4. An RGB input signal RGBin from a sensor S is applied to an RGB reconstruction filter 1 and to a Green uniformity restoration unit 3 is a present version, in a once line delayed version, and in a twice line-delayed version. The

RGB reconstruction filter interpolates missing red, green and blue pixels values on the basis of the signals applied to the filter in which, as apparent from Fig. 1, at each pixel position only one of the three colors R, G and B is present. A select box 5 selects between the original center Green pixel value Gc or a reconstructed center Green value Gc' from the RGB reconstruction filter 1, and the averaged Green signal avG from the Green uniformity restoration unit 3. If the edges in the Green area are smaller than the level Th, then the average Green value avG is selected. If the edges in the Green area are larger than the level Th, i.e. when high frequencies above that level Th have been detected, then the signal Gc or Gc' from the RGB reconstruction filter 1 will be selected.

By leaving out the upper horizontal line delay in the block diagram of Fig. 4, the circuit can be used for the single row RGB reconstruction and Green uniformity restoration on the basis of the pixels shown in Fig. 3.

Tests with pictures of existing Bayer image sensors, having column wise Green non-uniformity, proved that the mentioned algorithms eliminate that non-uniformity and maintain the resolution. The estimated improvement in signal-to-noise ratio is about 2 to 3 dB. (The estimation has been done by adding noise until both pictures give the same impression.) This improvement also holds for fixed pattern noise. Further this circuit can be applied for averaging the dark current of the image sensor.

The following salient features of the invention are noteworthy. The restoration of the Green uniformity of RGB Bayer image sensors without resolution loss. The restoration with the already available row delays needed for the RGB reconstruction. The inherent signal-to-noise improvement and possibility to filter the dark current of the sensor.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. For example, instead of the average value avG, a median value or any other low-pass filtered green signal can be used as long as it combines Green from at least one Red column and Green from at least one Blue column; any such alternatives are included by the expression "average value" in the claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware.

Claims:

1. A method of interpolating an output color signal (Go) of a given color in dependence on an input signal (RGBin) having first values of the given color which are influenced by a first other color and second values of the given color which are influenced by a second other color, the method comprising:

interpolating (1) an intermediate color signal (Gc') at positions where no signal of the given color is present;

generating (3) an average value (avG) of the given color in dependence upon both said first and said second values; and

furnishing (5) said output color signal (Go) in dependence upon both said intermediate color signal (Gc') and said average value (avG).

2. A method as claimed in claim 1, wherein said furnishing step (5) depends on a presence of contours in said input signal (RGBin).

3. A device for interpolating an output color signal (Go) of a given color in dependence on an input signal (RGBin) having first values of the given color which are influenced by a first other color and second values of the given color which are influenced by a second other color, the device comprising:

means for interpolating (1) an intermediate color signal (Gc') at positions where no signal of the given color is present;

means for generating (3) an average value (avG) of the given color in dependence upon both said first and said second values; and

means for furnishing (5) said output color signal (Go) in dependence upon both said intermediate color signal (Gc') and said average value (avG).

4. A camera, comprising:

a sensor (S) for furnishing an input signal (RGBin) having first values of a given color which are influenced by a first other color and second values of the given color which are influenced by a second other color; and

a device as defined in claim 3.

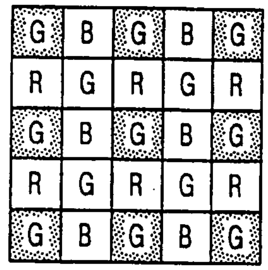

FIG. 1

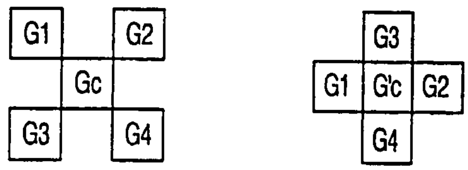

FIG. 2

FIG. 3

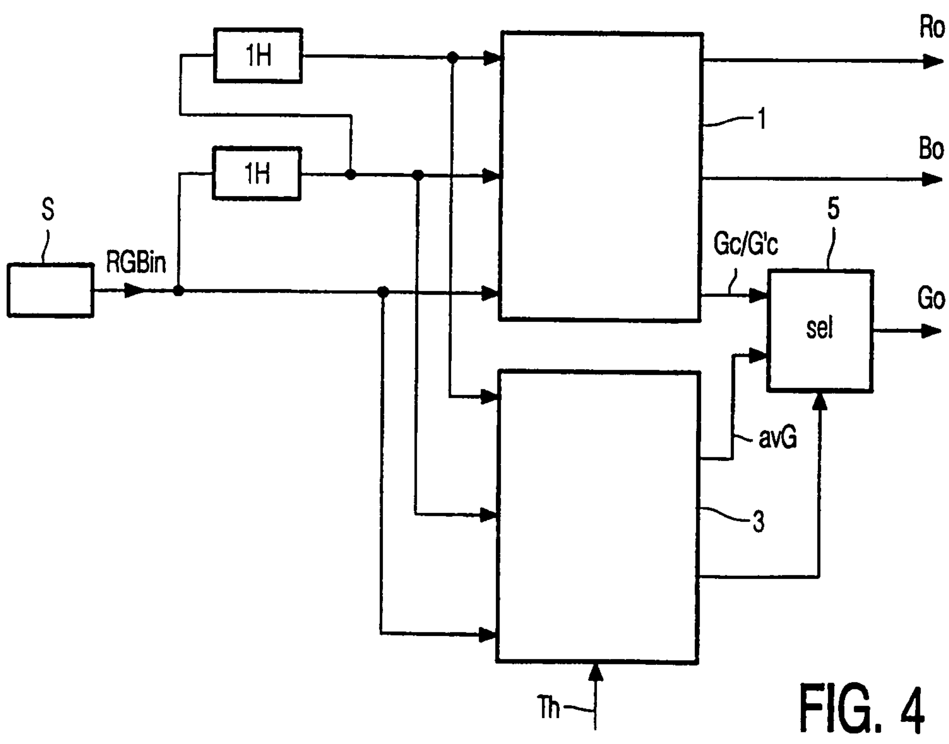

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 99/00073

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04N 9/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5333055 A (HARUHIKO MURATA ET AL), 26 July 1994 (26.07.94), column 3, line 56 - line 63, figure 19e	1,3-4
A		2
	--	
A	EP 0729278 A2 (SANYO ELECTRIC CO., LTD.), 28 August 1996 (28.08.96), see the whole document	1-4
	--	
A	US 4176373 A (PETER L.P. DILLON ET AL), 27 November 1979 (27.11.79), see the whole document	1-4
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 July 1999	08-07-1999

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5614947 A (YUKIHIRO TANIZOE ET AL), 25 March 1997 (25.03.97), see the whole document --	1-4
A	US 5172227 A (YUSHING T. TSAI ET AL), 15 December 1992 (15.12.92), see the whole document -- --------	1-4

INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5333055 A	26/07/94	JP 2698276 B	19/01/98
		JP 6046431 A	18/02/94
		JP 2686203 B	08/12/97
		JP 6046305 A	18/02/94
		JP 2513554 B	03/07/96
		JP 6292211 A	18/10/94
EP 0729278 A2	28/08/96	CN 1139337 A	01/01/97
		JP 8237672 A	13/09/96
		US 5852468 A	22/12/98
US 4176373 A	27/11/79	GB 2000937 A,B	17/01/79
		HK 41982 A	08/10/82
		JP 1271496 C	25/06/85
		JP 54018230 A	10/02/79
		JP 59048596 B	27/11/84
US 5614947 A	25/03/97	EP 0630159 A	21/12/94
		JP 7007736 A	10/01/95
		KR 146260 B	15/09/98
		JP 7107496 A	21/04/95
US 5172227 A	15/12/92	DE 69120661 D,T	20/02/97
		EP 0514535 A,B	25/11/92
		JP 5505084 T	29/07/93
		WO 9210911 A	25/06/92